Application of fusion power reactor to transmute minor actinides from spent nuclear fuel

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The work presents calculation analysis of dual-aimed Fusion Power Reactor (FPR) application for minor actinides transmutation and energy production simultaneously. Arrangement of long-life minor actinides (Np, Am, Cm) was proposed in the assemblies of FPR blanket which has modular configuration and surrounded Deuterium-Tritium plasma with 14.1 MeV neutron source. Blanket also contained lithium material for Tritium production and self-supplying the fusion reaction in plasma. Several FPR blanket compositions were considered in order to obtain optimum on three reactor parameters: transmutation rate of actinides, tritium breeding, power production. Tritium breeding ratio (TBR) was obtained at level 1.11 for water-cooling and reached up 1.56 in variant with helium-cooled assemblies with Np nitride. It was concluded that rows with actinides from processed waste fuel should be arranged near the plasma First Wall (FW). Transmutation calculations show that isotope Np-237 has 14 % burnout per full power year (FPY). Effective neutron-multiplication factor Keff in the reactor can be low (0.3–0.7) which fully excludes a possibility of uncontrollable power rise during in the reactor operation.

FPR possesses an inherent safety and it has a neutron abundance source for waste transmutations. Major parameters of waste assemblies and rods were taken similar to those of operating LWR to minimize guesses on effectiveness of other technologies. While considered neptunium oxides, nitrides and metallic compositions from processed spent nuclear fuel of fission reactors it was stated advantages of NpN.

Method for three-dimensional activation analysis of fusion reactor materials was used in transmutation calculations. MCNP neutron/photons three-dimensional transport and FISPACT inventory codes are used for optimization of minor actinides burn-up and tritium production rate in the blanket. Thermohydraulic and thermomechanic calculations are done by ANSIS code. Results show that nuclear heat deposition in waste fuel rods does not exceed the heat deposition in fuel elements of existing LWR.

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